NATIONAL ACADEMY OF SCIENCES

Number 29 • November 1959

IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs.

NBS Radio, Ionosphere, and Airglow Observations During IGY

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The following report is adapted from a more detailed treatment by David M. Gates which appeared in the Journal of Research of the National Bureau of Standards—D. Radio Propagation, *July-August 1959.*

The International Geophysical Year was selected to coincide with a period of maximum solar activity, which was likely to produce vast and diverse effects on the atmosphere of the earth. Since the ionosphere is primarily produced by solar irradiation of the upper atmosphere it was anticipated that the IGY period would be particularly suitable for a worldwide ionospheric physics observational program. For this purpose the regular observational program of the Central Radio Propagation Laboratory of the National Bureau of Standards in Boulder, Colorado, was enlarged and special experiments were set up. These experiments ranged from the large synoptic network of ionospheric vertical incidence sounding stations to equatorial forward scatter, sporadic-E, radio noise, night airglow, and observations of satellite transmissions through the ionosphere.

During the IGY period a close watch on the sun was kept by solar patrols distributed throughout the world utilizing visual, optical, photographic, photometric, and radio techniques.

The IGY World Warning Agency headed by R. C. Moore at the NBS station at Fort Belvoir, Virginia, was designated to process and filter data from this global network of patrol stations, to maintain a running account of the "state of the sun," and to alert the scientists of the world to periods of unusual solar activity. At times, during those Alerts, Special World Intervals were declared, thereby accelerating scientific observations in solar and upper atmosphere IGY research programs throughout the world. Before the IGY it had been thought that the forecast of two major storms during the entire IGY period would represent adequate success. Actually, about two-thirds of the severe geomagnetic disturbances during IGY were predicted.

IGY Ionospheric Vertical Sounding Observations

During the International Geophysical Year a large network of vertical incidence ionospheric sounding stations (about 150) was placed in operation throughout the world. Since the vertical incidence pulse technique is one of the most reliable methods for obtaining a measure of the electron

density and the electron density profile of the ionosphere, it was important to establish stations of this nature at as many strategic locations as possible. Prior to the IGY the National Bureau of Standards operated 20 stations throughout the world, while during the IGY it operated directly or cooperated with other agencies in the operation of 34 stations. All stations were on a 15-minute basic-sounding schedule. Much of the reduction of the data was done at the stations, but all data sent to Boulder on a monthly or bimonthly basis were reviewed in order to assure smooth and consistent operation of the program. The vertical incidence program at the National Bureau of Standards has been under the direction of A. H. Shapley, R. W. Knecht, and H. G. Sellery.

Equatorial Close-Spaced Chain: Interesting results have come from the ionospheric soundings from the equatorial close-spaced chain of stations in South America. These stations were located at Talara, Chiclayo, Chimbote, Huancayo, and La Paz. In Figure 1 the variation of electron density at fixed heights is shown for the 24-hour period at Huancayo. These curves are typical of the other four stations as well. The sharp increase at sunrise in the electron density should be noted as well as the fact that the intermediate levels attain a maximum electron density earlier than the higher levels of the ionosphere. Particularly notable is the abrupt rise in height of the electron density at sunset, an effect considerably larger than expected from straight recombination alone.

Equatorial sporadic E ("clouds" or patches of increased ionization in the E region) occurs during most daylight hours throughout the year at stations near the equator. It appears on the ionogram as a diffuse trace often extending 20 km or more in height and seldom blanketing the F region echoes. Figure 2 shows the percent-

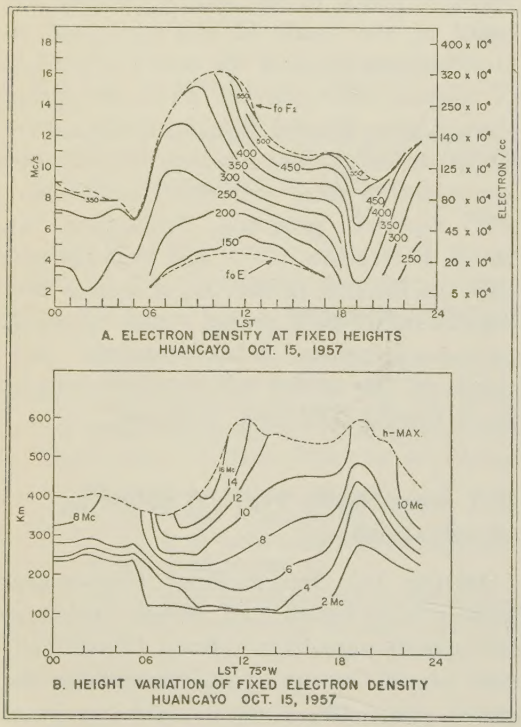

Fig. 1. *Height-Density Relationships at Huancayo, Peru.*

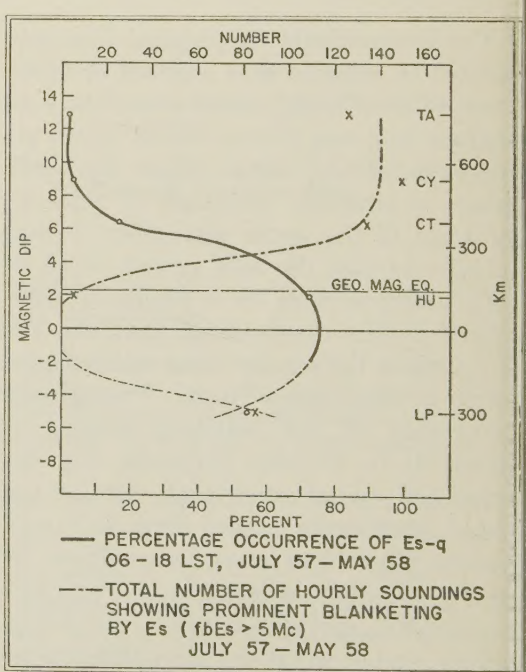

Fig. 2. *Occurrence of Equatorial Sporadic E as a Function of Magnetic Dip of Station. TA = Talara, CY = Chiclayo, CT = Chimbote, HU = Huancayo, and LP = La Paz.*

age occurrence of equatorial sporadic E as a function of the magnetic dip of the station. Eleven months of data (July 1957 through May 1958) were averaged to obtain the percentages for Talara, Chiclayo, Chimbote, and Huancayo; however, only one month of data was available for La Paz. From the curve it is clear that this form of sporadic E is a very distinctive equatorial phenomenon, and that it occurs with a frequency greater than 35 percent only within a belt spread about 5.5° to either side of the geomagnetic equator and has dropped to a frequency of only 5 percent by 8° from the geomagnetic equator. Although earlier workers had suggested a somewhat wider belt for equatorial sporadic E, recent IGY experiments on the earth's magnetic field in the vicinity of the geomagnetic equator by S. E. Forbush, as recently reported by H. Odishaw, give a similar width to the equatorial electrojet.

Although the equatorial sporadic E persisted throughout most days of the year, occasionally it would disappear suddenly for periods of minutes to hours in the early afternoon. S. Matsushita has established a definite lunar dependence for this effect, which suggested that a similar relationship might hold true for the time of first appearance of equatorial sporadic E, since these times varied from as early as 0600 to as late as 1000. In contrast, the late afternoon disappearance occurred regularly between 1730 and 1830. In order to test this hypothesis the data for Huancayo from May 1957 to April 1958 were divided into the three seasons (equinox and June and December solstices). Three-day running means of the times of first appearance were computed and plotted against the lunar phase as shown in Figure 3. A lunar correlation is clearly evident in the equinoctial and December-solstice curves with equatorial sporadic E appearing earlier in the morning on days of new and full moon. The data for the June solstice do not suggest quite as strong a lunar control; however, as more

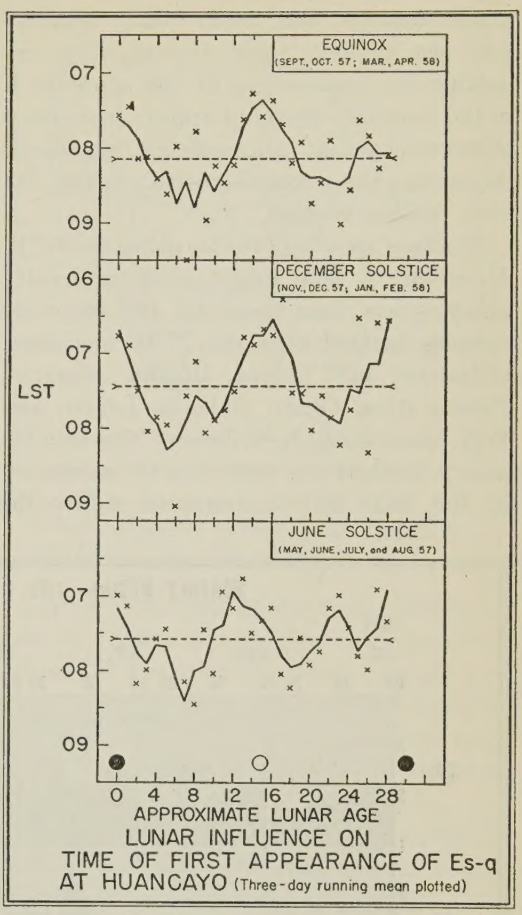

Fig. 3. *Lunar Influence on Appearance of Equatorial Sporadic E.*

data become available the scatter of the points may be reduced. Matsushita had explained the lunar effect for the midday disappearance in terms of ionospheric electric currents. He assumed that the equatorial sporadic E was caused by the vertical drifting of electrons in the eastward-flowing electric current and that the lunar tides induce a westward-flowing counter-current which reduces the strength of the sporadic E. Pursuing these arguments further, Knecht of the Central Radio Propagation Laboratory points out that during the new and full moon the lunar-induced current adds an easterly flow to the already established solar-induced easterly during the early morning hours; during the first and

third quarter the lunar tide counteracts the easterly solar current, thus retarding the appearance of the sporadic E in the morning. It would appear from these observations that Matsushita's hypothesis concerning the electron-current systems has been further verified.

Electron Density Profiles along the 75°W Meridian: A true height electron density analysis has been made for the following stations located near the 75°W meridian: Chimbote and Talara, Bogota, Panama, Puerto Rico, Grand Bahama Island, and Fort Monmouth, New Jersey. The Budden matrix method was used with the assistance of the IBM 650 computer to reduce the ionogram data. Another computer program was used to interpolate the values of electron density at fixed heights, compute the height of the maximum and integrate the electron density up to h_{max}. This research was carried out at NBS by J. W. Wright and G. H. Stonehocker.

Hourly ionograms from the seven stations were reduced to give true heights of reflection at intervals of 0.2 mc from 1.8 mc to f_0F_2 (critical frequency of the F2 layer, i.e., the frequency at which total reflection occurs). Several usual ionospheric features show up, but, in addition, an increase in electron density occurs over Bogota during the late evening hours and a

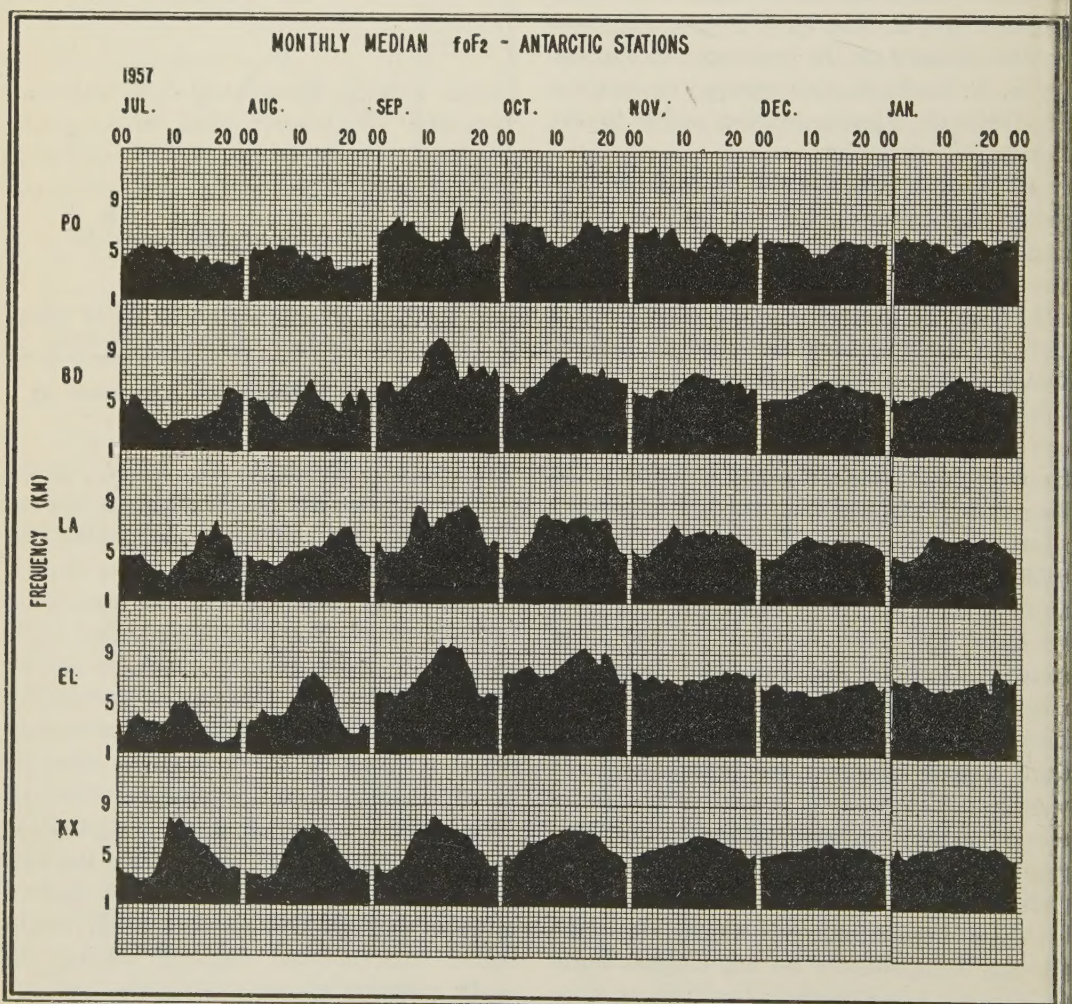

Fig. 4. *Results of Vertical Incidence Soundings at Five US-IGY Antarctic-Stations.*

bulge develops in the ionosphere over the equator. This bulge may be the result of some form of tidal action but at the moment it is not fully understood.

Vertical Incidence Soundings from Antarctica: During the IGY the first sizeable network of ionospheric vertical incidence stations on the Antarctic continent was established. Of approximately a dozen stations, five were operated by the U.S. at the Pole, Byrd, Little America, Ellsworth, and Wilkes IGY stations. The data reported here represent the first from high-latitude southern stations and the first ever obtained at either the North or South Pole. Prior to making these observations there was considerable question concerning the state of the ionosphere above the South Pole, whether the ionosphere could exist throughout the 6-month period of darkness, whether diurnal variations existed in the polar winter ionosphere, and the nature of the f_0F_2 variations over the Antarctic continent. The present data, representing the period June 1957 to May 1958, definitely supply the answers to some of these questions.

In Figure 4 are shown, for five of the Antarctic stations, the monthly median values of f_0F_2 plotted against time of day for each hour. For the Wilkes and Ellsworth Stations, the normal temperate latitude behavior is seen with the diurnal variation reaching a maximum around midday. For the Little America and the Byrd stations the maximum is reached during the evening hours and for the Pole there appears to be a weak diurnal variation with the maximum occurring in the early morning hours. It is curious indeed that the ionosphere over the Pole in July has minimum f_0F_2 values which are greater than those over any other station. This is particularly surprising since throughout July the atmosphere above the Pole is not illuminated below an altitude of about 450 km. As expected, the summertime (December) f_0F_2 values exhibit relatively little diurnal variation.

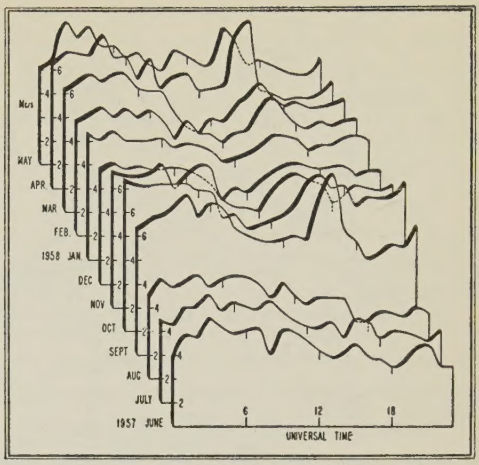

Fig. 5. *Ionospheric Profiles at South Pole Station. Monthly median values of f_0F_2 for each hour of the day are shown.*

Winter soundings at the Pole show that there is considerable ionization present as low as 250 km while the sun's rays do not strike below 450 km for July. Particularly noteworthy in the summer is the constancy throughout the day of the critical frequency for E, F_1, and F_2.

A more detailed picture of the monthly median values of f_0F_2 for each hour of the day for the period June 1957 through May 1958 is shown in Figure 5. The winter months (June, July, August) have the lowest f_0F_2 values and appear to have a 24-hour wave, whereas the equinox and summer values are higher and exhibit a 12-hour variation. A harmonic analysis of the monthly median values of f_0F_2 for these data is shown in Figure 6 for the 24-, 12-, 8- and 6-hour components. The 24-hour component shows the winter values occurring at 0600 UT to be 90° out of phase with the summer values at approximately 0000 UT, thus suggesting that the F-layer density in the darkened part tends to reach a maximum during those hours when the auroral zone has the maximum amount of sunlight for that time of the year. The 12-hour wave appears at 0400 and 1600 UT and the 8-hour wave at 0730, 1530, and 2330 UT. The 6-hour wave appears indefinite.

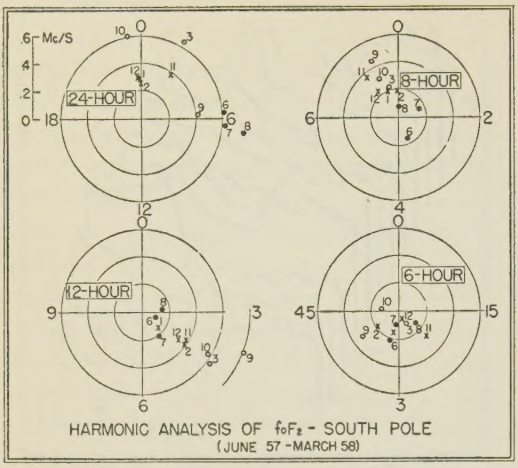

Fig. 6. *Harmonic Analysis of South Pole Data from Fig. 5.*

Although the analysis is still in progress it would appear that a significant diurnal variation occurs in the f_0F_1 and f_0E during the polar summer. The principal wave seems to have a 24-hour period, showing a maximum at 2200 for f_0F_1 and at 1300 for f_0E. Even more striking is the summertime, daylight behavior of f_0F_2, f_0F_1, and f_0E monthly mean values for the Pole Station when plotted against Zurich sunspot number as shown in Figure 7. It would appear from these results that over the Pole the F_2 region of the ionosphere becomes weaker, the E region strengthens, and the F_1 region is relatively insensitive to increased solar activity. This occurs at the time of the year when the polar ionosphere is completely and continuously illuminated. By comparison, it is well known that at stations throughout the world, the critical frequency for each region of the ionosphere increases with increasing sunspot number, since the increased solar activity produces an increase in ionizing radiation. Certainly it appears that the data from the Pole Station are unique in many respects. They raise several questions which unfortunately may not be answered until a much more detailed analysis is carried out. In certain instances further data will need to be obtained from the Pole Station and careful comparison made with data from other Ant arctic stations. Fortunately, the scientif observational program is continuing i Antarctica during 1959, although at a re duced level.

VHF Equatorial Forward Scatter Experiments

Before IGY, experiments in VHF ion spheric forward scatter had been primaril conducted in north temperate latitudes an in the auroral zone, and not in the vicinit of the magnetic equator, where the ion sphere behaves differently and in a mann little understood. In this region are exhib ited such phenomena as equatorial sporadi E, equatorial spread F, and a strong da time current-system girdling the earth the 100-km level, known as the "equatori electrojet." Amateur radio communicatio spanning the magnetic equator (e.g., b tween Buenos Aires and Mexico City) ha been sustained on the 6-meter band (ne 50 mc) during evening hours of equinocti periods at times of sunspot maximum, su

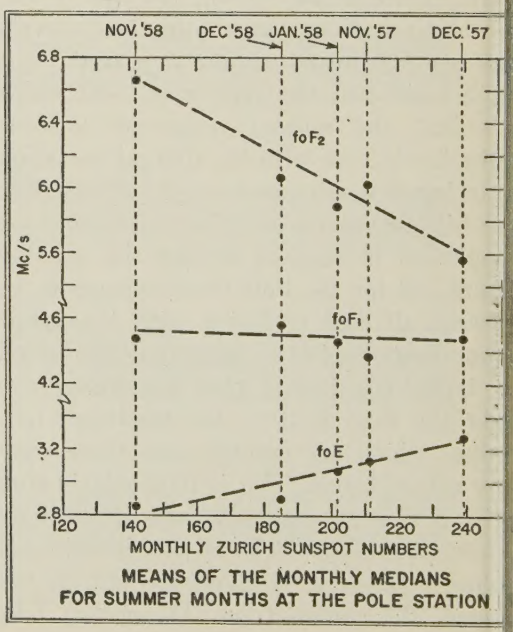

Fig. 7. *Effect of Solar Activity on Ionosphere at South Pole.*

gesting unusual ionospheric conditions in the equatorial zone.

To provide a systematic study of ionospheric irregularities and other effects which might support ionospheric propagation at 50 mc across the magnetic equator, an IGY experiment was set up in South America. A basic E-scatter circuit was installed between Arequipa and Trujillo, Peru, while the long-distance circuit between Antofagasta, Chile, and Guayaquil, Ecuador, was operated to observe scattering associated with effects in the lower F region. These circuits, centered on the magnetic equator at Huancayo, recorded over a 1-year period so as to enable the study of seasonal and diurnal variations as well as more rapid changes in the equatorial ionosphere. R. Cohen and K. L. Bowles were the project leaders. (See Figure 8.)

The basic equipment for the forward scatter experiments consisted of large rhombic antennas, high-powered (3 kw or 20 kw interchangeable) transmitters, and sensitive narrow-band receivers. The transmitting stations at Antofagasta, Chile, (49.960 mc), and Arequipa, Peru, (49.920 mc) and the receiving stations at Huancayo, Peru, Trujillo, Peru, and Guayaquil, Ecuador, employed 1000-foot rhombic antennas directed along the several great-circle paths. One transmitting station, Huancayo, Peru, (49.880 mc), and the two receiving stations at Clorinda, Argentina, and Sao Paulo, Brazil, utilized stacked pairs of 5-element Yagi antennas. The Huancayo installation also had a small low-powered 100-w transmitter feeding a Yagi antenna directed toward Guayaquil. This circuit is intended for detection of the sporadic E between Huancayo and Guayaquil.

Two east-west circuits were installed along the 20° isocline, to receive signals from Antofagasta at Clorinda, Argentina, via the E region and at Sao Paulo, Brazil, via the F region. These circuits were installed to compare equatorial east-west propagation, insofar as possible, with the north-south propagation, as well as to check

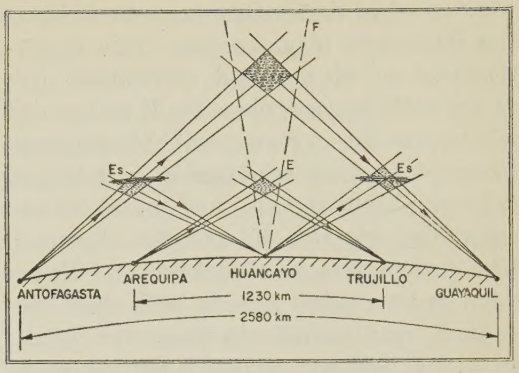

Fig. 8. *Forward Scatter Circuits from Huancayo. F = F layer; E = E layer; and Es = sporadic E.*

on the southern range of latitude over which equatorial effects are encountered. The presence of transmitters and receivers appropriately spaced permitted the reception of signals at Huancayo from Antofagasta, at Trujillo from Antofagasta, and at Guayaquil from Arequipa, in addition to the basic circuits previously mentioned and the Huancayo-Guayaquil circuit. Thus there are three symmetrical E-scatter paths, as well as two asymmetrical paths, which permit the simultaneous observation of E-region effects at various latitudes. Ionospheric effects in this extensive region near the magnetic equator are particularly sensitive to latitude. Further details concerning the same ionospheric regions are provided by the records from the close-spaced chain of ionospheric sounders along the west coast of South America.

Over the two paths, Antofagasta to Guayaquil and Arequipa to Trujillo, the short-term daytime variations in the signal intensity appear to correlate very closely. Indeed, over all six circuits, the daytime signal traces appear to correlate reasonably well while nighttime correlations are poor. Comparisons with the vertical incidence soundings at Huancayo suggest that these daytime signals result from scattering by equatorial sporadic E. A close correlation exists, during certain periods studied, between the signal over the Arequipa to Trujillo path and the H component (horizontal

component of the earth's magnetic field) of the Huancayo magnetogram. This is particularly so when signal correlation over all six paths is good. Since the H component is interpreted as a measure of the equatorial electrojet, a close relationship is indicated between VHF signals, and perhaps also equatorial sporadic E, and the electrojet. The Antofagasta to Huancayo and Huancayo to Guayaquil records both show sporadic E signals similar to those over circuits in middle latitudes, while the curious aspect is that the circuit from Arequipa to Trujillo almost never exhibits this form of sporadic E propagation.

Often during the evening and nighttime hours on the Antofagasta to Guayaquil path (but not on the Antofagasta to Trujillo path) there is observed a strong signal increase which appears to correlate well with the occurrence of spread F on the vertical incidence sounder at Huancayo. While it had been expected that F-region scatter might take place over this long-path circuit much of the time, this is evidence that it can occur at night.

The cooperation and participation of the IGY committees of Argentina, Brazil, Chile, Ecuador, and Peru was an indispensable part of this experiment, and the assistance by the governments of these countries was greatly appreciated.

Radio Noise Network

Radio noise is a basic limitation to long distance radio reception, and in particular, the background of radio noise originating from natural causes in the atmosphere is often a severe restriction to good radio communication. Therefore, a detailed knowledge concerning the distribution of noise levels throughout the world and an understanding of the noise characteristics is fundamental to the advancement of communication techniques. For this reason, during the IGY a worldwide network of stations recording radio noise levels was put into operation by NBS under the supervision of W. Q. Crichlow, R. T. Disney, and C. A. Samson.

In any radio noise measurements the following three parameters are useful: (1) the mean power, (2) the mean envelope voltage, and (3) the mean logarithm of the envelope voltage. In addition to measurements made with the NBS Radio Noise Recorder, ARN-2, in the worldwide network instantaneous amplitude probability distributions were obtained at Boulder, Colorado. These distributions provide information concerning the detailed character of the noise from which its interference properties can be determined.

Preliminary results would indicate that the worldwide predictions published elsewhere are too simplified. The behavior of radio noise, as a function of the frequency, time of day and season, differs widely from location to location. Specific local conditions need to be well understood in order to make accurate predictions.

Thus, afternoon noise levels in areas of high local thunderstorm activity may be 25 to 30 db higher than indicated by the predictions. Boulder, Colorado is a good example of this, since it is located near one of the most active thunderstorm regions in the United States—the front range of the Rocky Mountains. On certain days the variation may be as much as 70 db, on some frequencies. In contrast, at Kekaha, Hawaii, the minimum noise levels for the low frequencies tend to occur near sunset instead of a few hours after sunrise as at most stations. As a result, the 160-kc afternoon noise levels appear to be 20 to 30 db lower than predicted at this location. The nighttime noise levels at Boulder are often lower than predicted, while at Kekaha they agree rather well with the predictions.

Radio Satellite Observations

With the successful launching, during IGY, of earth satellites, permanent interferometer equipment was installed at Table Mesa near Boulder to record transmission

passing through the ionosphere from these satellites. Pairs of half-wave dipoles, with horizontal east-west polarization at one third wave length above the ground, were set up at the corners of equilateral triangles of 3,000-foot and 150-foot spacing. Observations were made at both 20 and 40 mc. In addition, circularly polarized antennas were installed. The output is recorded on magnetic tape or on two 6-channel Sandborn recorders. The equipment is fully automatic and can be set for automatic operation during the passage of a satellite beacon transmitter at these frequencies. Two Yagi antennas on a frequency of 108 mc and a vertically polarized antenna for 20 mc have also been installed. With this arrangement of antennas, measurements of angle of arrival, Faraday rotation, polarization, scintillation, diversity effects, and Doppler frequency changes have been made. The satellite ionospheric measurements program at the National Bureau of Standards is under the direction of C. G. Little.

Inspection of the Faraday fading records of the 20 mc signals made during the first 4 months of satellite 1958 Delta (Sputnik III) show the following systematic variations in the fading rate: (a) The fading rate is slowest when the satellite is in the north and greatest when it is in the south; (b) the greater height of the satellite during the north-to-south passes, and hence the longer ionospheric paths of the radio signals, account for the greater fading rates during these passes than during the south-to-north passes; (c) nighttime passes are characterized by a fading rate that is much slower than for daylight passes at the same height. When the fading rate was compared with the square of the F-layer critical frequency, taken from the Boulder ionograms, it shows that the daily variations in fading rate are largely due to the daily variations in the ionization content of the ionosphere. Many of the Faraday-rotation rates, rather than varying smoothly throughout a single passage of the satellite, vary irregularly and indicate the existence of ionospheric irregularities. In some instances these irregularities are of the order of 100 km in lateral extent. Calculations using the 20 mc signal from 1958 Delta show that the observed irregularities in the Faraday rotation rate can be accounted for if the integrated electron content, along the line of sight, per square centimeter column, varies irregularly with variations of the order of 10^9 during 1-km change (horizontal) in satellite position. From a determination of the number of complete rotations of the plane of polarization of the radio signal, the total electron content, up to the height of the satellite, can be calculated. For a pass of this satellite, at a height of about 236 km, low in the F region, the integrated electron content in a vertical column was estimated as 2.7×10^{12} electrons/cm^2 column.

In conjunction with the satellite observations a computer program is being set up for tracing the paths of the rays between the satellite and the receiver. The ordinary and extraordinary rays are traced separately through the ionosphere and the difference in their phase paths gives the instantaneous orientation of their polarization vector. Actual ionospheric profiles from ionograms are used up to the F-region peak, but various assumed profiles are tried for the upper ionosphere. The ray-tracing program is coupled to a program which gives successive positions of the satellite along an elliptical orbit. The combination of these two programs gives a complete picture of the Doppler frequency, the Faraday rotation, and the angle of arrival of the satellite signal. A comparison between the direction of arrival and line of sight to the satellite gives a measure of the angular errors introduced by the ionosphere.

Airglow Observations

The atoms and molecules of the earth's upper atmosphere continuously radiate a flux of light and radiation. During the daylight hours this flux is swamped by a much

stronger energy flux from the sun, but at night the airglow emitted from the high atmosphere can be easily detected by sensitive photometers and on occasion it can be seen by the human eye. Closely related to the airglow emission, and perhaps a part of the same phenomenon, is the well known and often observed aurora associated with high-latitude belts on the earth. Because of its wide distribution and constant occurrence, it was logical that a worldwide study of the airglow be undertaken as a part of the IGY synoptic program. F. E. Roach has directed the NBS airglow program, involving observation stations at Fritz Peak, Colorado, and Rapid City, South Dakota. In addition, the group constructed photometers for College, Alaska; Huancayo, Peru; and Sidney, Australia. The photometer itself is of a hybrid design combining the Lyot birefringent filter principle, as adapted by J. Blamont and A. Kastler and used by R. B. Dunn and E. Manring, with the telescope system designed by F. E. Ross. The telescope has a 6-inch objective, a focal length of 13 inches, and a 4-degree field of view. A series of color filters permit the selection of one of the following emissions characteristic of the night airglow: OI ($^1S_0 - {}^1D_2$) at 5577 A, OI ($^1D_2 - {}^3P_1$) at 6300 A, and NaI ($^2P_{3/2} - {}^2S_{1/2}$, $^2P_{1/2} - {}^2S_{1/2}$) at 5890 and 5896 A. In addition there are many strong bands of emission in the infrared from the OH molecule. The photometer is programmed to sweep the sky in successive almucantars (circles of the celestial sphere parallel to the horizon) at angles of 80°, 75°, 70°, 60°, 40°, and the zenith. It sweeps the entire sky in 4 minutes at each wavelength and returns once each 15-minute interval to repeat the wave-length sequence. The data are recorded on a strip chart recorder and transferred to punch cards for IBM 650 processing.

In addition to the photometer described above, a simple photometer of the Roach-Elvey type was installed at Thule, Greenland, in October 1958 for special observations at the magnetic pole. There was also installed an all-sky camera and a patrol spectrograph at Fritz Peak and at Rapid City.

An analysis of the nightglow observations at 5577-A shows the emission to come from a height of approximately 100 km. Direct measurements of the altitude of the night airglow obtained from rockets show the maximum of the 5577-A layer to be near 98 km. Systematic isophote airglow maps of the night sky throughout many nights have been prepared and a careful analysis of these maps made. This analysis shows the sky to contain discrete airglow cells of 5577-A emission, having a characteristic diameter of 2500 km and moving with translational speeds of about 100 m/sec. These airglow cells appear to exhibit a rotational period of about 5 hours.

In order to investigate the possibility that the 5577-A night airglow, present over the earth as a whole, may be closely related to the aurora, which is prevalent in high-latitude regions, the CRPL investigators have made a statistical analysis concerning the frequency of occurrence of these phenomena. Although this type of statistical treatment is open to some question, it may give a clue as to whether or not these two phenomena, the airglow and the aurora, have a common origin.

World Data Center A—Subcenter for Airglow and Ionosphere

Located in the Boulder Laboratories of the National Bureau of Standards is IGY World Data Center A, Subcenter for Airglow and Ionosphere Data. The Data Center is under the supervision of W. B. Chadwick and S. M. Ostrow. To this subcenter, all airglow and ionospheric stations in the western hemisphere and Australia and New Zealand send their data for copying and filing. In this manner, a central file of the results of the IGY observations will be made available for research and study for many years to come. It was the responsibility of this subcenter during the IGY to

send or arrange for sending copies of the data to World Data Centers B, C1, and C2 located in the USSR, England, and Japan respectively. These centers in return send data from the laboratories in their area of responsibility to Boulder. This subcenter, in addition to maintaining files of the data, prepares catalogues and indexes of the data, makes copies of the data available to scientists, organizations, and others, and maintains office space where visiting research workers can come for study.

IGY Satellite 1959 Iota

Carrying the largest payload and the most varied set of experiments in the US-IGY satellite effort, 1959 Iota (Explorer VII) was launched on October 13, 1959, at 11:30:05 am EDT. The satellite was injected into orbit at 11:39:33 am EDT.

The approximate orbit of 1959 Iota as of October 14 was: Perigee, 344.5 statute miles; apogee, 677.9 statute miles; period, 101.35 minutes; inclination of orbit to equator, 50.3°; velocity at perigee, 17,275 statute miles per hour; and velocity at apogee, 16,034 statute miles per hour.

1959 Iota was placed in orbit by the Army Ballistic Missile Agency, under sponsorship of the National Aeronautics and Space Administration, as a contribution to the IGY and its 1959 extension, International Geophysical Cooperation-1959. Although it is the last of the satellites scheduled as part of the US-IGY and IGC-59 programs, scientific results from future United States satellites will continue to be contributed to the international space science program being coordinated by the ICSU Committee on Space Research (COSPAR).

Scientific experiments carried by 1959 Iota include measurements of the earth's radiation balance, heavy primary cosmic rays, solar ultraviolet radiation and X-radiation, micrometeorites, cosmic rays and less energetic particles, lifetime of an unprotected solar cell, and surface and interior temperatures. In addition, the 20 mc primary telemetry frequency and its 40 mc and 60 mc harmonics permit ground-based studies of the ionosphere.

Launching

1959 Iota was placed in orbit by a Juno II launching vehicle modified by the addition of a support cylinder to the fourth stage to support the weight of the payload.

This was the fifth firing of the Juno II vehicle. Previously it had been used to launch successfully the space probes Pioneer III and Pioneer IV, and in the unsuccessful attempts to launch the forerunner of 1959 Iota on July 16, 1959, and a 12-foot inflatable sphere on August 14, 1959.

The Juno II rocket system has four stages, is 76 ft long overall, and weighs about 60 tons including fuel. The first stage is a modified Jupiter rocket developed by ABMA. The Jet Propulsion Laboratory of the California Institute of Technology developed the upper stage assembly consisting of 15 scaled-down solid-propellant Sergeant rockets. The second stage contains 11 of these rockets, each 42.5 inches long

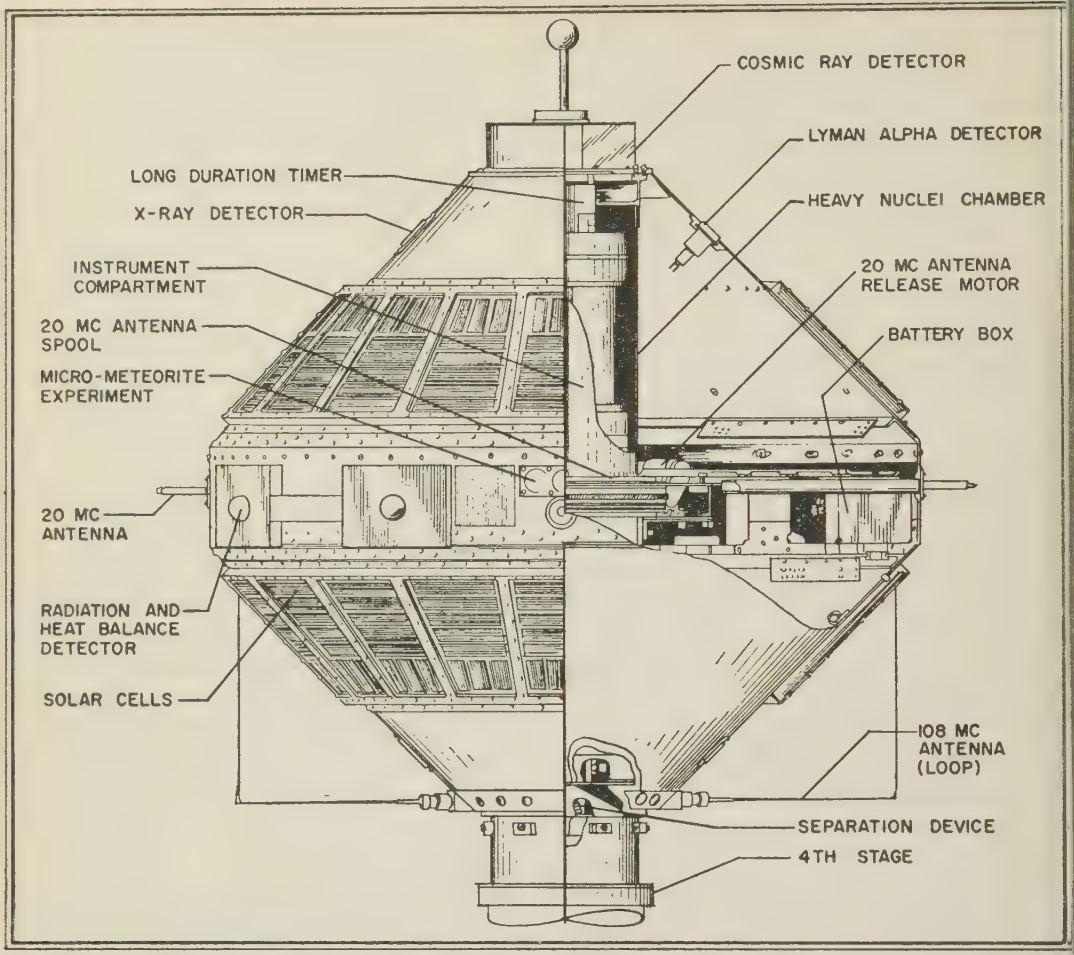

Fig. 9. *1959 Iota, Carrying Largest Payload of US-IGY Satellite Effort, In Cutaway View. Adapted from a US Army photograph released by NASA.*

and 6 inches in diameter, arranged in cylindrical fashion. A cluster of 3 similar rockets fitted inside the cylinder is the third stage. The fourth stage, to which the payload is attached, is a single rocket fitted inside the third stage cluster.

During launch and first-stage flight, the whole upper stage cluster is protected by an aerodynamic shroud which is released by explosive bolts and pushed aside by a lateral rocket prior to upper stage ignition.

The Delta Minimum Inertial Guidance Scheme, located in the forward part of the first stage, furnishes guidance for the vehicle. Once trajectory information has been fed into this guidance system, prior to ignition, it operates automatically. The only ground-to-vehicle control is the safety destruct system.

Satellite Characteristics

1959 Iota weighs 91.5 lbs. Shaped like a double cone joined by a center ring, the satellite is 30 inches long and 30 inches wide at maximum diameter. Its shell is composed of plastic-impregnated Fiberglass

Experiments and Instrumentation

The successful launching of 1959 Iota brought to fruition planning by the USNC

IGY Technical Panel for the Earth Satellite Program under the chairmanship of Richard W. Porter. Herman E. LaGow, Head of NASA's Planetary Atmospheres Branch, was the satellite project officer. The satellite was designed, fabricated and tested by ABMA under the direction of Ernst Stuhlinger and Joseph Boehm.

Radiation Balance Measurements: This experiment is being conducted by Verner E. Suomi of the University of Wisconsin. It is a study of the thermal radiation budget which is thought to influence greatly the earth's weather.

Near the equator, the earth receives more energy from the sun than it radiates into space; conversely, it radiates more energy into space in polar regions than is received there from the sun. The transfer of energy from lower latitudes to higher latitudes is being studied in this Wisconsin experiment by measuring direct radiation from the sun; the fraction of this radiation diffusely reflected by the earth, clouds and atmosphere; and the fraction of radiation which is converted into heat by the earth and ultimately re-radiated back into space in the far infra-red portion of the spectrum.

Six sensing elements are used: two hemispheres and one sphere painted black to measure total energy at all wavelengths; one hemisphere painted white to measure radiation of longer wavelengths while reflecting shorter wavelengths; and two sensing elements (Tabor sensors) with a special coating to measure short wavelengths only. The Tabor sensors are about one inch in diameter, the black and the white sensors about one and one-quarter inch in diameter. The measurements are made by means of thermistors, or electronic thermometers, contained in each sensor.

Solar Ultraviolet and X-radiation Measurements: This experiment is being conducted by Herbert Friedman, Superintendent of the Atmosphere and Astrophysics Division, US Naval Research Laboratory, with the assistance of Talbot A. Chubb and Robert W. Kreplin of NRL. The purpose of the experiment is to measure solar ultraviolet and X-ray intensities and their variations, particularly during solar flares.

Solar ultraviolet, or Lyman-alpha, radiation is being measured by means of two photosensitive ionization chambers cylindrical in shape, three-quarters of an inch in diameter, and one and one-quarter inches long. The chambers are fitted with windows of lithium fluoride transparent to wavelengths of 1040 to 1340 Angstroms; the only radiation of notable intensity in this band is the Lyman-alpha line of atomic hydrogen at 1216 Angstroms.

The two X-ray detectors are similar in size and shape to the Lyman-alpha ionization chambers. The X-ray ionization chambers are filled with argon gas, have beryllium windows, and are sensitive to wavelengths of 3 to 15 Angstroms.

A photo cell is included in this experiment to enable the experimenters to determine the aspect of the satellite with respect to the sun.

Heavy Primary Cosmic Ray Measurements: This experiment was designed by the late Gerhart K. Groetzinger of the Martin Company's Research Institute for Advanced Studies (RIAS). It is being carried on by Martin A. Pomerantz, director-elect of the Bartol Research Foundation, and Philip Schwed, also of RIAS. The experiment is designed to determine the flux of heavy primary cosmic rays with atomic numbers greater than 6 (carbon), 9 (fluorine), and 16 (sulfur). It uses an ionization chamber closed at both ends and filled with argon gas. The voltage maintained between an insulated metallic wire along the axis of the cylinder and the wall of the chamber is such that the wire collects all the electrons produced by the passage of charged particles through the argon gas. The total charge reaching the central wire is proportional to the total ionization generated by the particle and hence measures the charge of the particle.

Ground-based Ionospheric Observations: The 20 mc primary telemetry frequency (and its two harmonics) selected for the transmitter in this final US-IGY satellite provides an opportunity for researchers to learn more about the earth's ionosphere. IGY-sponsored ionospheric investigations are being conducted by G. W. Swenson, Jr., University of Illinois; C. G. Little, National Bureau of Standards, Boulder, Colorado; G. C. Reid, University of Alaska; O. G. Villard, Jr., Stanford University; W. J. Ross, Penn State University (with slave stations for simultaneous observations at Charlottesville, Virginia, and Columbus, Ohio); W. P. Dyke, Linfield Research Institute, McMinnville, Oregon. In addition, scientists throughout the world received advance word of the precise frequencies in order to make appropriate preparations for additional ionosphere studies. The world scientific community was also informed of the successful launch of 1959 Iota through AGIWARN and COSPAR.

Micrometeorite Measurements: This experiment is being conducted by Herman E. LaGow of NASA; the work was initiated when he was at NRL. A cadmium sulphide photo conductor is covered with an optically opaque film. An impact of a micrometeorite larger than about 10 microns in diameter will damage the film and permit sunlight to enter the cell. This causes a drop in the output resistance of the detector. Information about orientation of the cells is provided by data from Friedman's solar aspect cell.

Cosmic Ray Measurements: This experiment is being conducted by James A. Van Allen of the State University of Iowa, assisted by George H. Ludwig, who planned and designed the instruments, and William Whelpley, who was in charge of constructing and testing them. Two Geiger-Mueller tubes are measuring cosmic radiation and less energetic particles in the lower fringes of the inner Van Allen radiation belt and the space just below. One tube, an Anton 302 similar to that flown in 1958 Epsilon (Explorer IV), is unshielded; it is ¾ inch in diameter and 3 inches long. The other tube, an Anton 112 about ⅞ inch in diameter and 2½ inches long, has a lead shield about 1 mm thick.

Exposed Solar Cell Measurement: This experiment is being conducted by ABMA and the US Army Signal Research and Development Laboratories to determine the performance of an unprotected solar cell in a space environment. The effect of erosion upon a silicon cell mounted on the equator of the satellite is indicated by variation in the voltage developed by the cell when illuminated by incident light.

Temperature Measurements: Temperature measurements are being made in an isolated area of the satellite surface, in a solar cell cluster, in a battery pack, and in one of the Geiger-Mueller tubes.

Radio Equipment

1959 Iota carries two radio transmitters. One transmitter, powered by solar cells, transmits all data except micrometeorite measurements continuously on 19.9915 megacycles. It transmits over a turnstile type antenna consisting of four flexible quarter wavelength elements. This transmitter also radiates two harmonics at 39.9830 and 59.9745 megacycles. The all-transistor transmitter feeds 600 milliwatts to the antenna at fundamental frequency, and 15 milliwatts and 3 milliwatts respectively at the second and third harmonics.

The second transmitter, powered by chemical batteries, transmits micrometeorite data and a tracking signal continuously at 108.00 megacycles. This transmitter feeds 15 milliwatts to a modified loop antenna.

The solar cells are located in six clusters of 481 cells each, so arranged that attitude control for the satellite is not required. An automatic timing device will cut off the solar-powered transmitter one year after launching. The nickel-cadmium batteries

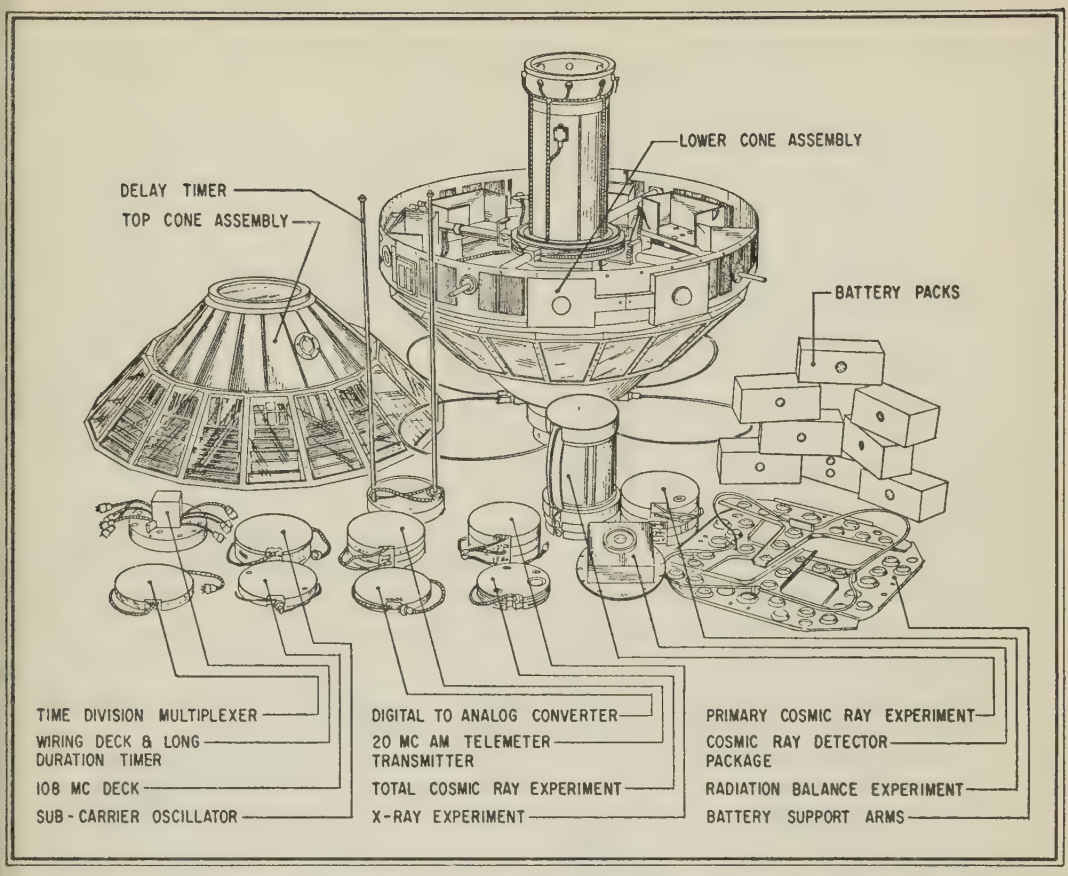

Fig. 10. *Partially Disassembled View of 1959 Iota Showing Some of Experiments Carried. Adapted from a U. S. Army photograph released by NASA.*

supplying power to the 108 megacycle transmitter are expected to have a lifetime of about two months.

Tracking

More than 20 stations around the world are tracking 1959 Iota and recording scientific data. NASA Minitrack stations at Blossom Point, Maryland; San Diego, California; Santiago, Chile; Esselen Park, South Africa; and Woomera, Australia, are equipped both for tracking and data acquisition. The Minitrack stations at Quito, Ecuador; Lima, Peru; and Antofagasta, Chile, are tracking the satellite on 108 megacycles. The University of Heidelberg in the German Federal Republic is recording 20-megacycle information.

Initial tracking of 1959 Iota was accomplished by US Army Microlock stations at Aberdeen Proving Ground, Maryland; Cape Canaveral, Florida; Huntsville, Alabama; Cape Hatteras, North Carolina; Fort Monmouth, New Jersey; Van Buren, Maine; and on Bermuda.

Baker-Nunn cameras at twelve stations around the world and the worldwide network of Moonwatch teams, both supervised for NASA by the Smithsonian Astrophysical Observatory, also are tracking the satellite.

Solar Radio Astronomy at Fort Davis, Texas

The following report was prepared by A. R. Thompson of the Harvard Radio Astronomy Station at Fort Davis.

The Radio Astronomy Station at Fort Davis, Texas, was established by Harvard College Observatory under the auspices of the US Air Force in the late summer of 1956. A radio counterpart to the optical solar observatory at Sacramento Peak, New Mexico, the main purpose of the station is to provide a continuous record of the radio bursts emitted by the active sun.

Observations were begun during September 1956 with equipment which records the complete spectrum of solar radio bursts in the frequency range 100–580 megacycles per second. The observations covered the whole of the International Geophysical Year, and are being continued.

Since it was planned to use sensitive sweep-frequency equipment covering almost three octaves of the radio spectrum, it was mandatory to select an observing site at which the level of man-made interference is very low. For this reason, the station was located in a remote valley in the Davis Mountains of West Texas. The surrounding mountains rise about 1500 feet above the level of the site, and provide excellent shielding from unwanted radio signals. The station is virtually free from interference at frequencies above 40 mc/sec, only one weak television signal and a few intermittent radio-telephone signals ordinarily being detectable. The site was chosen by Alan Maxwell, who has directed the program at Fort Davis since its inception.

Equipment and Experimental Techniques

The first use of sweep-frequency equipment for the study of solar radio bursts was by J. P. Wild and his colleagues in Sydney, Australia, and proved to be a great advance over single-frequency techniques. With sweep-frequency records, a simple system of classification of the bursts, closely related to the different physical processes by which they are generated in the solar atmosphere, is possible. Moreover, solar bursts are immediately distinguishable from intermittent man-made interference.

At Fort Davis, the frequency range 100–580 mc/sec is covered in three bands, 100–180, 170–330, and 300–580, by three separate receivers. In January 1959, two additional receivers and display channels, covering the ranges 25–50 and 50–100 mc/sec, were added, so that the present observing range is 25–580 mc/sec.

Each receiver sweeps through its band continuously at a rate of three times per second. The three high-frequency receivers are connected to separate broad-band primary feeds at the focus of a 28-foot paraboloid antenna. This antenna is equatorially mounted and tracks the sun from rising to setting throughout the day. The two low-frequency receivers are connected to fixed arrays that do not track the sun, but have broad beams directed along the meridian at the celestial equator, so that the sun can be monitored for the greater part of the day. The outputs of the receivers are displayed on separate cathode-ray tubes, which are intensity-modulated and photographed by a continuously moving film; the film records the intensity of the bursts as a function of frequency and time.

The equipment is switched on automatically at sunrise each day and the receivers are calibrated in frequency and intensity after sunset each evening. In the daily observing routine, great emphasis is placed on continuity of observations, and an average of less than 5% of possible observing

ime has been lost through equipment fail-
ire, etc.

More than 90% of solar radio emission ecorded at Fort Davis can be divided into he four spectral classes shown in Fig. 11.

Noise storms (Type I) consist of a series of irregular radio-frequency bursts, often superimposed on an enhanced background of steady radiation. They may last for many hours, or even days, and are associated with the presence of large sunspots.

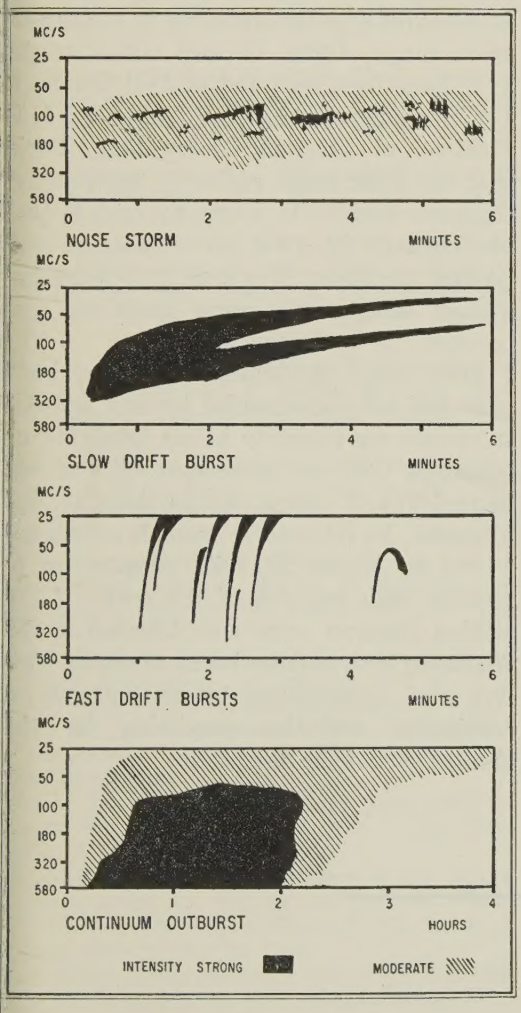

Fig. 11. *Idealized Examples of the Records of the Four Spectral Types of Solar Radio Bursts. A special form of fast-drift burst, known as an inverted "U" burst, is also shown.*

Slow-drift bursts (Type II) are characterized by a band of emission that drifts steadily toward the lower end of the frequency spectrum over a period of about five minutes. They are often very intense and show a high degree of association with the occurrence of solar flares. *Fast-drift bursts* (Type III) last for a few seconds only, and drift rapidly toward lower frequencies. They are very common, often occurring in groups. More than 10,000 fast-drift bursts per year have been recorded at the Fort Davis station. The great *continuum outbursts* (Type IV) are intense bursts of radiation lasting for as much as 12 hours and often covering several octaves of the radio-frequency spectrum.

The film records are analyzed at Fort Davis, and all bursts are classified according to spectral type and listed with time of occurrence and intensity. Quarterly summaries of the radio bursts were distributed by the station during the IGY, and publication of this information is continuing through the International Astronomical Union (Zurich) *Quarterly Bulletin of Solar Activity*, and the Central Radio Propagation Laboratory (Boulder, Colorado) *Monthly Bulletin of Solar Geophysical Data.*

A detailed analysis of observations taken during the first two complete years of operation, October 1956 through September 1958, has now been made. This analysis includes correlation of the four types of bursts with solar flares and prominences, geomagnetic activity, and variations in cosmic-ray intensity, and an investigation of the duration and intensity of solar bursts as related to their interference with communications signals. (Several reports on these analyses by personnel of the Fort Davis Station have been published or are now in the process of publication.)

The slow-drift bursts and the great continuum outbursts present the most interesting associations with other geophysical phenomena; these are briefly reviewed below.

Slow-Drift Bursts

About 30 slow-drift bursts per year are observed at Fort Davis during solar maximum. The origin of a slow-drift burst is currently attributed to oscillations in the solar atmosphere at the local plasma frequency, which varies with the electron density. The drift of the burst toward lower frequencies therefore indicates that the point of origin moves outward through the solar atmosphere, traversing regions of progressively lower electron density.

From the rate of change of the frequency of emission, it is estimated that the rate of motion of the source is about 1000 km/sec. This is similar to the velocity usually attributed to solar auroral particles, and corresponds to a time of travel between the sun and the earth of approximately 40 hours. The suggestion immediately follows that a slow-drift burst may be caused by the emission during a flare of a stream of auroral particles, exciting plasma-frequency oscillations as it traverses the sun's corona.

The Fort Davis observations show that a significant association exists between the occurrence of slow-drift bursts and of subsequent geomagnetic storms. During September 1957, seven slow-drift bursts were recorded at Fort Davis; this was the greatest number for any month during the IGY. September 1957 was also the month of greatest geomagnetic activity ever recorded. Six major magnetic storms occurred, and five of these were preceded by slow-drift bursts recorded at Fort Davis. Over the two-year period October 1956–September 1958, at least 60% of magnetic storms were preceded by slow-drift bursts. Unfortunately, the available sweep-frequency data, recorded both at Fort Davis and Sydney, Australia, covers on the average just less than 2/3 of each day, and it is therefore impossible to know whether all magnetic storms were preceded by slow-drift bursts.

Continuum Radiation

The intense, long-duration examples of continuum radiation are perhaps the most spectacular of solar outbursts in the meter wave range. About 15 such outbursts per year have been recorded at Fort Davis. It has been suggested by A. Boischot and J. H. Denisse, of Meudon Observatory, Paris, that the solar radio outbursts accompanying great cosmic-ray increases, such as that of February 23, 1956, were cases of continuum radiation. However, no sweep-frequency observations were made on that occasion to verify this suggestion.

Most great continuum outbursts, however, are not accompanied by any increase in cosmic-ray intensity at sea level, but on occasions they are associated with an enhanced flux of cosmic-ray particles at high altitudes. An interesting example of this occurred on August 22, 1958, when a flux of protons with energies of the order of 170 million electron volts was detected by K. Anderson with balloon-borne counters. This flux was accompanied by an outburst of continuum radiation persisting for the greater part of the day.

IGY Bibliographic Notes

This is the sixteenth of a series of bibliographic notes on IGY and IGC-1959 programs and findings. The references are selected largely from a bibliography under preparation in the Science and Technology Division of the Library of Congress. (An interim IGY bibliography, covering the period January 1951-August 1958, prepared by the Library and published by the Academy with support of the National Science Foundation, is available from the Academy, 2101 Constitution Avenue, N. W., Washington 25, D. C., for $1.00. The 64-page volume contains 704 references.)

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Preprinted from *Transactions, American Geophysical Union*, Vol. 40, No. 4, Dec., 1959

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